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July 28th, 2004

From: General Aviation Human Factors Program Manager, ATO-P Human Factors R&D
To: General Aviation TCRG

Subj: GENERAL AVIATION HUMAN FACTORS THIRD QUARTER '04 REPORT

Ref: General aviation human factors execution plans (http://www.hf.faa.gov/gafunded.htm)

1) Each project is listed below.

a) Human Error and General Aviation Accidents: A Comprehensive, Fine-Grained Analysis using HFACS

Human factors quality assurance (HFQA). CAMI has completed the human factors quality assurance of the general aviation human factors data. The HFQA consists of reviewing all pilot-rater classifications of NTSB subject and modifier codes for each accident using HFACS (over 35,000 classifications total). This process began in December, but was delayed a few months due to some pop-up priorities (e.g., the Air Tour Accident analysis and the Emergency Medical Service Accident analysis). Both the event and causal factor databases will be provided to AAR-100 for inclusion in the web-based version of HFACS (see above).

HFACS rotorcraft analysis. Preliminary analyses of accidents involving emergency medical service (EMS) rotorcraft were completed. The preliminary findings were presented to Mr. Bill Wallace (AFS-840). The findings will be presented at the 2004 Air Medical Transport Conference in Cincinnati, Ohio, in October. A draft technical report will be available in the first quarter of FY05.

HFACS Analysis of Air Tour Accidents. Preliminary analyses of Air Tour accidents has been completed. The preliminary findings were briefed to Mr. Paul Joly (NRS Air Tour Operations). Previous analyses included 14 CFR Part 135 operations. With the completion of the HFQA, 14 CFR Part 91 data will be included in the final report. A fine-grained analysis of the unsafe acts of operators is also planned. A tentative delivery date for the final report is the first quarter of FY05.

Fine-grained analysis of GA accident data. With the delivery of the HFQA data, the University of Illinois will complete the fine-grained analysis of the general aviation data. A final report will be delivered in September of 2004.

All available information indicates the project is on track.

b) Comparison of the Effectiveness of a Personal Computer Aviation Training Device, a Flight Training Device and an Airplane in Conducting Instrument Proficiency Checks.

The researcher presented an abstract at the Aerospace Medical Association 75th Annual Scientific meeting and another abstract was accepted for the 48th Annual Meeting of the Human Factors and Ergonomics Society meeting.

Taylor, H.L., Talleur, D.A., Rantanen, E.M., Emanuel, T.W. (2004). *The Effectiveness of Personal Computers (PCATDs) and Flight Training Devices (FTDs) on Instrument Training for Pilots*, Aerospace Medical Association 75th Annual Scientific meeting.

Abstract During the past decade the Institute of Aviation, University of Illinois has investigated the effectiveness of PCATDs and FTDs for instrument training. The first study completed in 1996 indicated the PCATDs were effective for teaching all instrument tasks. As a result of this finding the FAA issued an advisory circular which permited PCATDs to be used for 10 hours of training toward the instrument rating. The next study indicated that the PCATD was effective in maintaining instrument currency. Both the groups of subject training in the PCATD and the FTD were more effective than a control group that received no training for 6 months. In addition they were at least as effective as the airplane in maintaining currency. The next study showed that the most effective amount of training in a PCATD was 5 hours compared to 10 and 15 hours. We recommended that the additional 5 hours of PCATD training permitted by the FAA be used for cross country training. Preliminary results of a current study indicates that the recommendation is valid. A final study in progress appears to indicate that there is no difference between the PCATD and the FTD in conducting IPCs and that the airplane appears to be more effective than either of them. The implication of these results to pilot training will be discussed.

Johnson, N.R., Rantanen, E.M., Talleur, D.A. (2004). Criterion setting for objective fourier analysis based on pilot performance metrics, Human Factors and Ergonomics Society 48th Annual Meeting.

Abstract: This study reports the development and evaluation of time series based objective pilot performance metrics. From a previously developed array of autocorrelation and Fourier analysis based metrics, five Fourier-based metrics that employed a threshold value were chosen to investigate their effectiveness in separating pilots who, based on instructor pilot (IP) evaluations, had either passed or failed a particular segment of an instrument proficiency check flight. An instrument landing system (ILS) approach was chosen for analysis based on IP feedback of what flight segments were most difficult to evaluate, had greatest sensitivity to overall pilot performance, and greatest criticality to the flying task. Further analysis showed that an optimal value for the criterion value could be found that most effectively separated those pilots that had passed the ILS segment from those who had failed. Criterion setting methods without external criteria using multidimensional scaling and cluster analysis techniques are also discussed.

All available information indicates the project will be completed in FY04.

c) Credit for Instrument Rating in a Flight Training Device or Personal Computer: Phase III: Transfer of Training Effectiveness of a Flight Training Device (FTD).

AVI 130
A total of 27 students enrolled in the AVI 130 Basic Instrument course for the spring semester 2004, but one student's data won't be included in the project and one student dropped the class. The subjects were assigned as follows: Airplane three; PCATD 5, two; FRASCA 5, seven; FRASCA 10, three; FRASCA 15, six; and FRASCA 20, four. This assignment is expected to provide approximately an equal number of subjects in each group when these subjects complete AVI 140.

AVI 140
A total of 30 students enrolled in the AVI 140 Advanced Instrument course for the spring semester, but two student's data won't be included in the project.

As a result of the subjects completed during the spring semester and those remaining in the project that will complete the project during the summer and the fall semesters, the "best case" analysis clearly shows that we will not have 20 subjects in each group. At best based on the current number of subjects remaining in the project we will have the following n's in the 6 groups at the completion of the project in Fall 04: Airplane=19; P5=18; F5=21; F10=18; F15=18; F20=18.

The most likely case based on our drop out rate is about one less subject per group will be in the final N when the project is completed in the fall. The reason for the short fall in subjects is due to a larger number of remedial students and drop outs during the fall '03 and spring '04 semesters. Our original estimate of the number of subjects at the end of the fall 04 was based on our previous experience with remedial students (AVI 102), drops, withdraws, etc. and those rates did not hold for the 03-04 school year.

All available information indicates the project is on track.

d) Visibility in the Aviation Environment

Dr. Mizokami has begun applying Dr. Bruno Olshausen's "sparse coding" analysis to natural images . We have continued to develop training software to teach pilots how to recognize distance, relative direction, and altitude of targets. A basic "beta" version of this software should be available soon after the last quarter of this year. Data collection has continued for images in the aviation environment as proposed in Phase 1 of the project. We have also continued to collect a series of inflight images of other aircraft using a stabilized telephoto lens. We have also begun to develop software to test pilot target detection capabilities on various backgrounds composed of aviation images. We have continued to refine the training device (target size/distance card) submitted at the last quarter with feedback from other researchers.

Our best accomplishment this quarter is Dr Mizokami's impressive progress in learning and implementing sparse coding algorithms for aviation scenes. This is a complex algorithm which required that I purchase and implement a more advanced version of Matlab software and a dedicated computer. Dr Mizokami has already successfully analyzed smaller single natural images and will proceed to develop automated methods to complete the analysis on larger and multiple images. It should be noted that in its current form, the analysis is computationally demanding and requires long processing periods (currently many hours per image).

All available information indicates the project is on track.

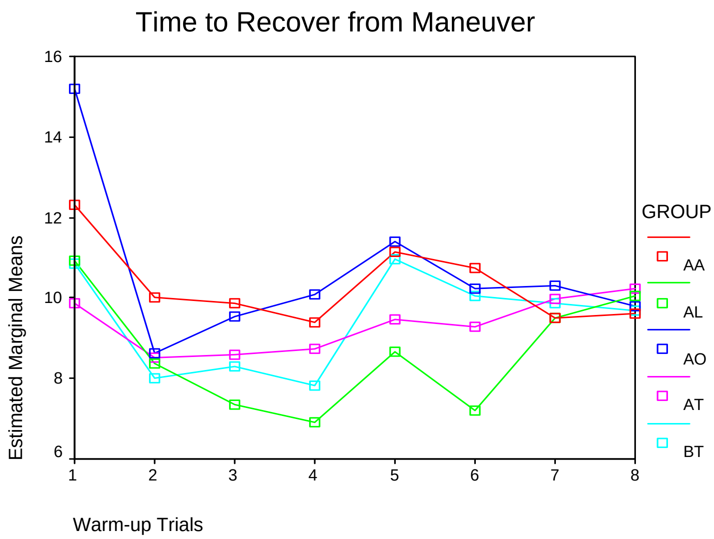
e) Electronic Primary and Multi-function Flight Displays for GA; Certification Criteria and Usability Assessments.

Data collection was completed for the electronic Primary Flight Display (PFD). The purpose of the study was to determine whether the addition of a terrain presentation on an electronic PFD would negatively impact pilots' abilities to recover from unusual attitudes and to determine whether additional guidance cues would augment recovery time. Forty pilots participated in the study, each group of eight using a different display format. The five conditions consisted of combinations of terrain depiction (none, full-color terrain, brown terrain) and guidance indications (pitch and roll arrows). The first display consisted of a traditional attitude indicator (blue sky, brown ground) with airspeed, altitude and vertical speed presented in tape format along the left and right edges of the display. The second display was identical to the first, but had guidance arrows for pitch and roll recovery. Pitch arrows were linear and appeared when the aircraft attitude was greater than 13 degrees up or down and disappeared when the aircraft was within 5 degrees of zero pitch, pointing from the aircraft symbol to the horizon. Roll arrows were curvilinear (arc form) and appeared when the aircraft exceeded 25 degrees of bank and disappeared when the aircraft was within 10 degrees of zero bank, pointing from the plane of the wings to the horizon line. The third display was similar to the first except that the brown portion of the display was replaced with photo-realistic (full-color) terrain. The fourth display was the same as the third display, but it included the guidance arrows. The final display was similar to the first display, but the “ground” or brown portion of the display was replaced with brown (polygon-based) terrain imagery.

All pilots performed 8 warm-up recovery maneuvers, using the basic electronic attitude-direction indicator (EADI) on the PFD, to familiarize them with the performance of the AGARS and with the basic functioning of the PFD. Following the eight practice trials, each pilot then performed 16 additional recovery maneuvers using the PFD that was assigned to their group. Two different orders were used and balanced across the groups. The maneuvers consisted of pitch up (20°), pitch down (15°), roll left or right (60°), pitch up (20°) and roll left or right (60°), and pitch down (15°) and roll left or right (60°). Half of the headings were selected to end the recovery facing mountainous terrain higher than the aircraft altitude and half were selected to end the recovery facing terrain lower than aircraft attitude. Pilot recovery times and initial response times were recorded for each trial. A five-way mixed analysis of variance was performed on the data.

Recovery was determined when the pilot had reached ±2.5 degrees of pitch and ±5.0 degrees of bank and was able to maintain those values for 3 seconds. The elapsed time at the end of three seconds was then recorded at the time-to-recover.

Multivariate Analysis of Variance indicated there were no significant differences between the displays. Figure 1 depicts the results from the familiarization trials. Initially, the groups differed in their performance, but by the last two trials all groups were performing with similar recovery times. This shows a learning curve for the basic PFD and suggests that the groups had equivalent performance prior to the start of the experimental trials. Figure 2 represents recovery time across experimental trials.



Key to Figures 1 through 7 -
Group assignments for Experimental trails:
AO = Display 1; Attitude (EADI) only
AA = Display 2; Attitude plus Guidance Arrows
AT = Display 3; Full-color Terrain
AL = Display 4; Full-colored Terrain plus Guidance Arrows
BT = Display 5; Brown Terrain

Figure 1. Mean time to recover from unknown attitudes by group and warm-up trial number (all trials with conventional EADI).

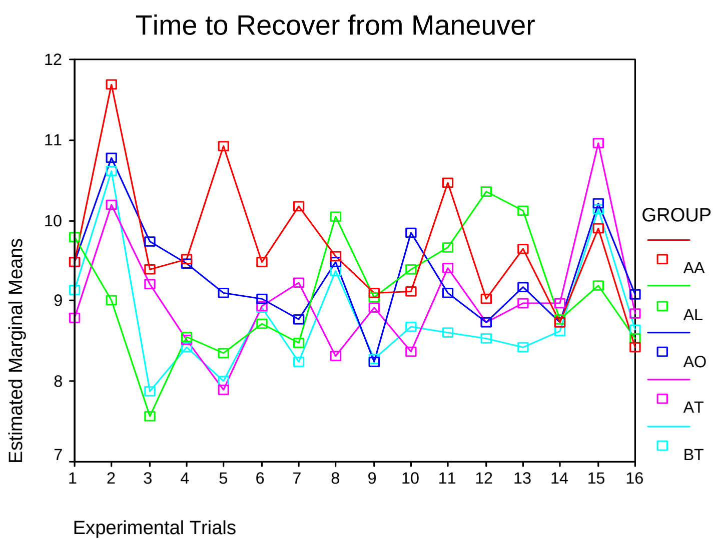


Figure 2. Mean times to recover from unknown attitudes by displays type and experimental trial.

Further univariate analyses were conducted to determine if type of maneuver resulted in any significant differences between display types. Again, no significant differences were found between displays and type of maneuver. See Figures #3-7.

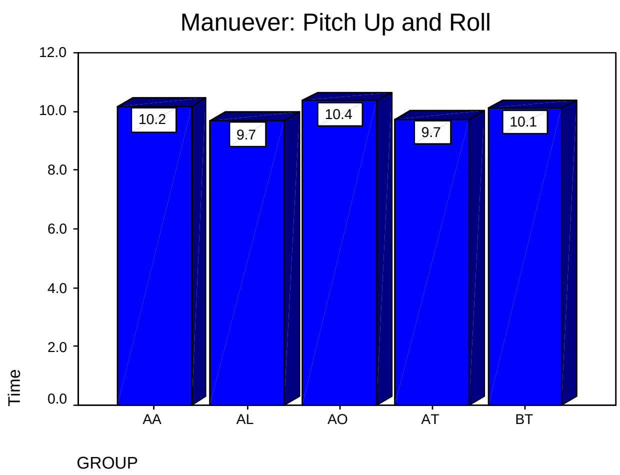


Figure 3. Mean time to recover from unknown attitude by display type: 15 degrees pitch up and 60 degrees bank.

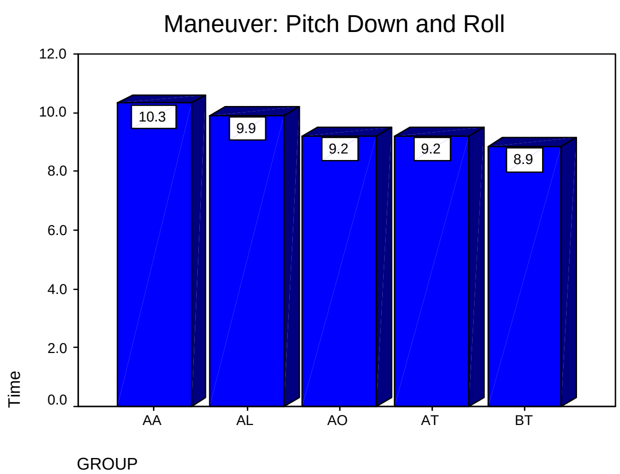


Figure 4. Mean time to recover from unknown attitude by display type: 10 degrees pitch down, 60 degrees bank.

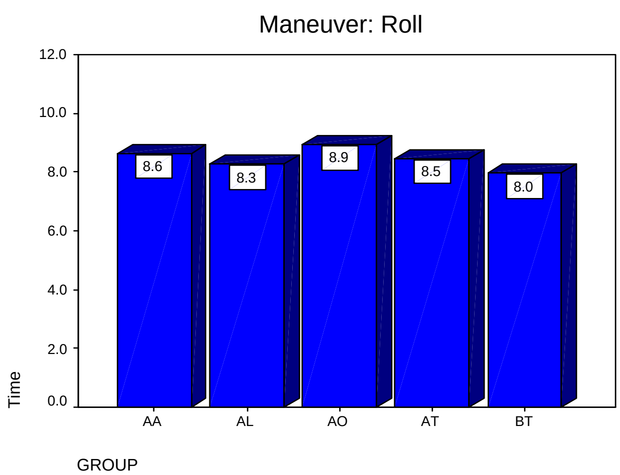


Figure 5. Mean time to recover from unknown attitude by display type: 60 degrees bank

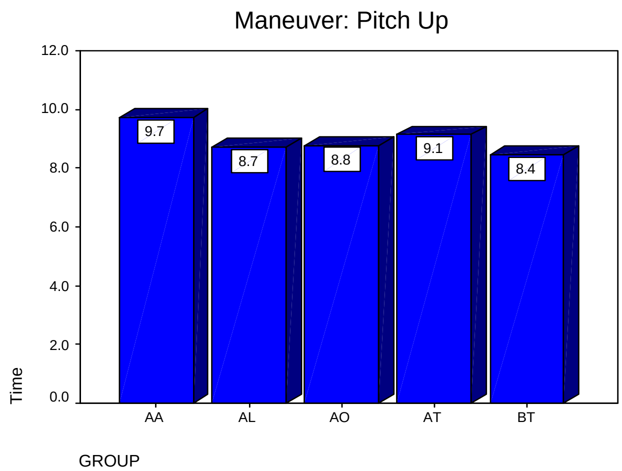


Figure 6. Mean time to recover from unknown attitude by display type: 15 degrees pitch up.

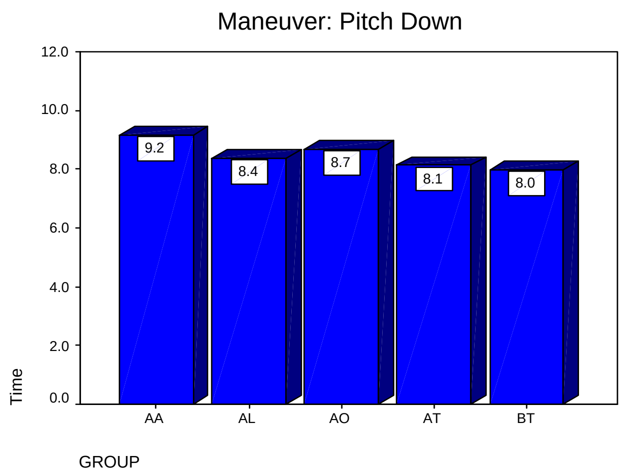


Figure 7. Mean time to recover from unknown attitude by display type: 10 degrees pitch down.

A few additional trials were performed by most of the participants to address specific questions raised by Aircraft Certification. First, there was an expressed concern that background terrain that was at a significantly higher elevation than the aircraft could cause recoveries to be made to the terrain horizon and not the zero-pitch line. Those participants flying a terrain-depicting display flew an additional pitch-up trial where the top of the mountainous terrain was ten degrees above the zero-pitch line. Only one of the participants showed any indication of holding the nose of the aircraft above the zero-pitch line rather than completing the recovery. Second, there had been an expressed concern about the display's effects on recoveries from inverted attitudes. Participants in all display groups flew one recovery from approximately 165 degrees of bank, and there did not appear to be any consistent effects of display type on pilot performance.

Pilots indicated that they were focusing their attention on the zero-pitch line, which was relatively prominent, and did not regard the terrain depictions, when present, as significant contributors to their recovery task. Thus it would appear, for this specific task, that the presence of a zero-pitch line of sufficient contrast (white with black borders) to all backgrounds allows pilots to adequately perform recoveries from unknown attitudes. Although the directional-guidance arrows produced a positive qualitative response from the participants, they did not appear to produce any significant or consistent quantitative difference in performance. Data are undergoing further sorting and analysis to look at possible localized effects and interactions for specific entry attitudes and displays.

All available information indicates the project is on track.

f) FAA/Industry Training Standards (FITS)

Activities performed during the last quarter included presentations of the preliminary findings and recommendations at the annual meeting of the Center of Excellence in General Aviation Research (CGAR) meeting held in Grand Forks North Dakota and at a meeting with Robert Wright the Manager of General Aviation and Commercial Division, and Thomas Glista Manager for General Aviation Training standards at FAA headquarters. Reviews of the potential impact of FITS on GA pilot training were also held with Jens C. Hennig from the General Aviation Manufacturers Association and Steve Casner from NASA Ames. A draft review of the transition syllabus and standards for TAA aircraft was also completed by our consultant.

Indications are that this activity is on track and will be completed by FY04.

g) Migration of HFACS database to a web-based interface

HFACS internet database application (http://www.hf.faa.gov/hfacs) to allow users to query NTSB maintenance reports by HFACS or NTSB or NASDAC fields. To obtain access to the searchable database, please contact at Dr. Krebs at william.krebs@faa.gov. Researcher is working on the front end portal application to allow searches, pilot entry and administrative functions. He contacted NASDAC to get additional database fields that were not included in the original download from CAMI. Sent screenshots of the application to stakeholders to ensure application meets initial requirement.

All available information indicates the project is on track.

h) Unmanned Aircraft Vehicle Mishap Analysis

Review of UA accidents experienced by the U.S. Navy, Marine Corps, Army, and Air Force. In April and May, contacts were made with representatives from each of the military services for the collection of UA accident data. A technical report entitled, "The Role of Human Causal Factors in US Army Unmanned Aerial Vehicle Accidents" was downloaded from the internet. In addition, a report describing Human Factors issues related to UAV mishaps in the Air Force was received. Information was also collected during attendance of the Aerospace

Medical Association meeting in Anchorage, AK. Contacts were made at the first annual workshop entitled "Human Factors of Uninhabited Aerial Vehicles" in Phoenix, AZ, May 24-25. The workshop brought together researchers from the military, government, and industry, who are interested in the rapidly expanding world of remotely operated aircraft. Presenters focused on current human factors research related to the control and maintenance of these aircraft. Break-out sessions focused on the identification of important areas for future research, as well as the identification of training, selection, and certification issues.

Accident data has also been collected from the Navy, Army, and Air Force. A report summarizing the data is currently being written. A report summarizing UA accident data is being written. Two primary sources of accident information were collected from the Army. The first source was a report entitled "The Role of Human Causal Factors in U.S. Army Unmanned Aerial Vehicle Accidents" (Manning, Rash, LeDuc, Noback, & McKeon, 2004). The report was produced by the U.S. Army Aeromedical Research Laboratory and is a summary of 56 UA accidents that occurred between January 1995 and February 2003. The accident data were obtained from the U.S. Army Risk Management Information System (RMIS), maintained by the U.S. Army Safety Center (USASC), Fort Rucker, AL. The accidents were summarized using two taxonomies, a modified version of the Human Factors Analysis and Classification System (HFACS) (Shappell & Weigmann, 2000), and the Army accident investigation and reporting taxonomy, DA PAM 385-40 (Department of the Army, 1994).

The second source of information was a direct query of the RMIS system. The query examined all UA accidents contained in the RMIS database that occurred between January 1980 and June 2004. A total of 74 accidents were identified, the earliest of which occurred on March 2, 1989, and the latest on April 30, 2004.

Information regarding UA accidents for the Navy was collected from the Naval Safety Center. A summary of UA mishaps occurring between 1986 and 2002 was received from the Naval Safety Center in Pensacola, FL (Kordeen Kor, personal communication). The summary lists 239 mishaps, including the mishap level, date, location, and a brief description. The brief description, while not providing much detail, allowed the general classification of the mishap, including whether the mishap was human factors-related or not.

Air Force accident/mishap information was collected from the Air Force Judge Advocate General's Corps website, http://usaf.aib.law.af.mil/. The website gives the executive summaries of Air Force Class A mishaps, organized by year. A total of 15 Class A UA mishaps were retrieved from the website, covering the dates from December 6, 1999 to December 11, 2003. In addition to these executive summaries, a complete accident investigation board report of the December 6, 1999 accident was received electronically from Major Curtis McNeil of the Judge Advocate General's Corps office. Also, a summary of Air Force accidents and human factors issues related to UA, entitled "USAF UAV Mishap Epidemiology, 1997-2003" was received electronically from Major Anthony P. Tvaryanas, the author.

The final report is due to AVR on December 31st, 2004

i) <u>National Airspace Human Factors Integration Plan for Unmanned Aerial Vehicles</u>

We have begun collection, analysis, and summary of existing research literature on human factors issues in UAV flight. Documents collected thus far include multiple peer-reviewed papers, conference proceedings, and technical reports from laboratories in the U.S. and abroad. To date we have collected approximately 25 such documents. We have also begun communications to arrange lab visits and interviews with researchers studying human factors of UAV flight, and an information-gathering trip to Dr. Mark Draper's laboratory at Wright-Patterson AFB is planned for August. As part of this research effort, the Co-P.I. also attended a May conference on the human factors of UAV flight.

The final report is due to AVR on December 31st, 2004

j) <u>Flight Deck Technologies and Procedures, Discriminability Assessment of Proposed Traffic Symbol Set</u>

Sponsor: AIR-130 *pop-up* requirement initiated in April 2004.

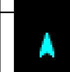
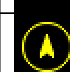
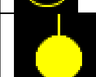
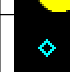
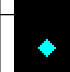
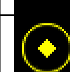
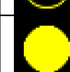
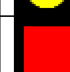
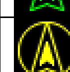
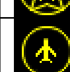
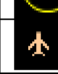
Objective: to evaluate whether traffic symbols proposed in the draft Advisory Circular, "Aircraft Surveillance Systems and Applications" meet the basic human factors requirement of discriminability?

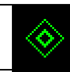
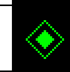
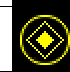
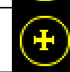
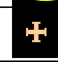
Background: Recent technological advances (e.g., ADS-B, TIS-B) afford the capacity to display traffic in the cockpit. More information is now available on traffic than in previous systems (e.g., TCAS), some of which could be coded in the traffic symbols on the display (e.g., by varying shape and color of the symbols). There is no consensus among manufacturers for the traffic display symbol set, prompting FAA Certification to propose an acceptable set in an appendix to their draft Advisory Circular, "Aircraft Surveillance Systems and Applications." Given that manufacturers may choose to implement the proposed symbol set, it is important that the proposed symbols be at least minimally evaluated for human factors considerations.

Technical Approach: The study was a descriptive psychophysical experiment where for each trial each participant was presented with a symbol in isolation and the participant indicates the perceived symbol from a separate list. Error rates and reaction time were recorded. The study included a preliminary test to determine the specific symbol set characteristics and implementation, and the viewing distances to be varied. A larger full experiment was conducted to determine the symbol set's ultimate discriminability performance.

Viewing distance condition was manipulated within subject. The design included 6 replications (6 orientations of the symbol or 1 orientation presented six times) by 19 symbols by 4 viewing distances (22”, 44”, 66”, and 88” monitor from the observer) for a total of 456 trials per subject. The dependent variables were accuracy and reaction time. The participant, seated before the apparatus, initiated each trial by pressing a key. With the key press, the cue display showed a small (approximate half inch) white crosshair in the center. Approximately 150 ms after the press the crosshair was removed and a single symbol appeared in the center of the display. After 250 ms, the symbol was removed. The participant recorded the perceived symbol by using a mouse to select it on the response display. Participants trained on the apparatus at the minimum viewing distance for 5 minutes before actual data collection trials. Each participant completed a block of all trials for a given viewing distance before the viewing distance is changed. Order of the viewing distance blocks were counterbalanced across participants. Participants were provided with a five-minute rest between each block.

Symbols included:

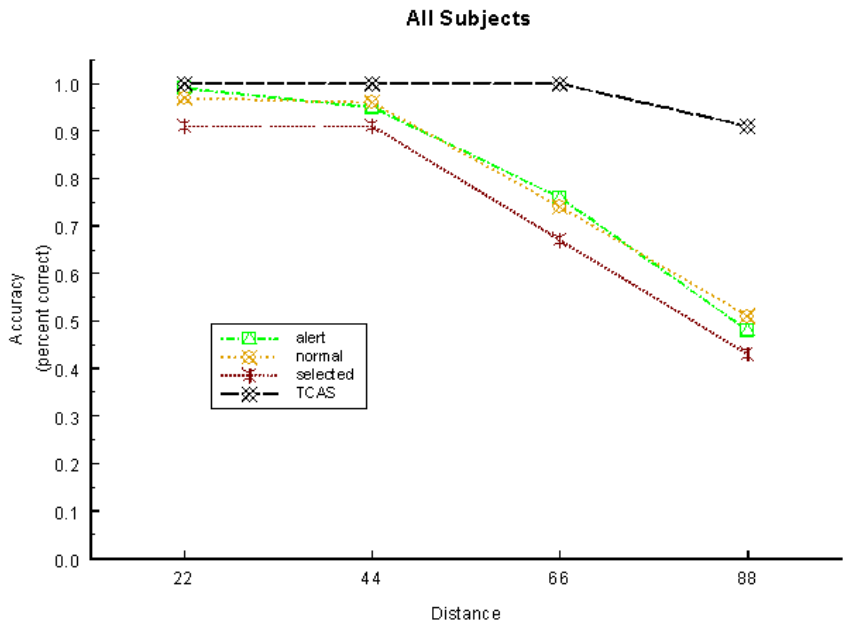
Directionality	**Selection**	**Plane**	**Alert**	**Symbol**
Directional	Unselected	Airborne	Non-proximal	
Directional	Unselected	Airborne	Proximal	
Directional	Unselected	Airborne	ASA Caution	
Directional	Unselected	Airborne	TCAS TA	
Non-directional	Unselected	Airborne	Non-proximal	
Non-directional	Unselected	Airborne	Proximal	
Non-directional	Unselected	Airborne	ASA Caution	
Non-directional	Unselected	Airborne	TCAS TA	
Non-directional	Unselected	Airborne	TCAS RA	
Directional	Selected	Airborne	Non-proximal	
Directional	Selected	Airborne	Proximal	
Directional	Selected	Airborne	ASA Caution	
Directional	Unselected	Ground	ASA Caution	
Directional	Unselected	Ground	Non-caution	

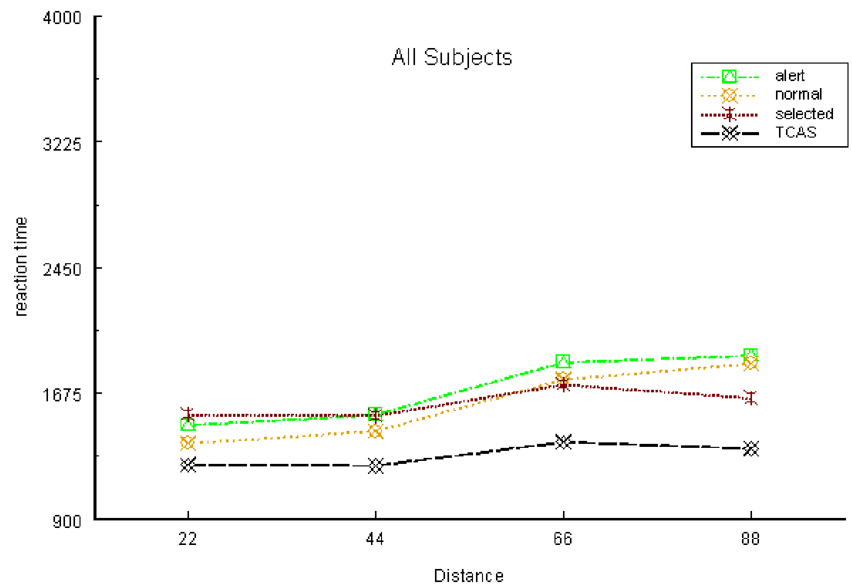
Non-directional	Selected	Airborne	Non-proximal	
Non-directional	Selected	Airborne	Proximal	
Non-directional	Selected	Airborne	ASA Caution	
Non-directional	Unselected	Ground	ASA Caution	
Non-directional	Unselected	Ground	Non-caution	

Symbols were grouped into four categories:

<u>Normal:</u> symbols 1, 2, 6, 7, 15, 20
<u>Selected:</u> symbols 11, 12, 16, 17
<u>Alert:</u> symbols 3, 8, 13, 14, 18, 19
<u>TCAS:</u> symbols 4, 9, 10

Preliminary Results: refer to figures below


All Subjects
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Accuracy
(percent correct)
alert
normal
selected
TCAS
22
44
66
88
Distance


4000
3225
2450
1675
900
reaction time
All Subjects
alert
normal
selected
TCAS
22
44
66
88
Distance

k) Unmanned Aircraft Operator Qualification and Training Requirements

ASU market survey announcement was posted on May 28th 2004. Twenty-eight institutions responded to the announcement. ATO-P Human Factors R&D formed a review panel to down select some of the institutions to submit a cost proposal. The panel will then review the second round to select the final institution(s) for this requirement. ATO-P Human Factors R&D anticipated start date is December 2004.

The final report will be due to AVR on December 31st, 2005

l) Human Factors Maintenance Considerations of Unmanned Aircraft

ASU market survey announcement was posted on May 28th 2004. Twenty-eight institutions responded to the announcement. ATO-P Human Factors R&D formed a review panel to down select some of the institutions to submit a cost proposal. The panel will then review the second round to select the final institution(s) for this requirement. ATO-P Human Factors R&D anticipated start date is December 2004.

The first report will be due to AVR on December 31st, 2005.

William K. Krebs